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THE GUIDE TO DESIGN FOR ON-ORBIT SPACECRAFT SERVICING (DFOSS) MANUAL: PRODUCING A CONSENSUS DOCUMENT

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ABSTRACT

Increasing interaction and changing economies at the national and international levels have accelerated the call for standardization in space systems design. The benefits of standardization--compatibility, interchangeability, and lower costs--are maximized when achieved through consensus. Reaching consensus in standardization means giving everyone who will be affected by a standard an opportunity to have input into creating that standard.

The DFOSS manual was initiated with the goal of developing standards through consensus. The present Proposed Guide derives from work begun by the Space Automation and Robotics Center (SpARC), a NASA Center for the Commercial Development of Space, and has continued as a standards project through the American Institute of Aeronautics and Astronautics (AIAA). The Proposed Guide was released by AIAA in January 1992 for sale during a one-year, trial-use period.

DFOSS is a response to the need for one document that contains all the guidelines required by on-orbit spacecraft servicing designers for astronaut extravehicular activity and/or telerobotic servicing. The manual's content is driven by spacecraft design considerations, and its composition has been achieved by interaction and cooperation among Government, industry, and research organizations. While much work lies ahead to maximize the potential of DFOSS, the Proposed Guide represents evidence of the benefits of industry-wide consensus, points the way for broader application, and provides an example for similar projects.

INTRODUCTION

The Design for On-Orbit Spacecraft Servicing (DFOSS) project commenced in 1988 at the Space Automation and Robotics Center (SpARC), located at the Environmental Research Institute of Michigan (ERIM) in Ann Arbor, Michigan. SpARC is one of 17 NASA-sponsored Centers for the Commercial Development of Space (CCDS).

CCDS centers are consortiums of academic, research, and private-sector institutions, which are committed to strengthening the bonds between Government, scientific, and industrial organizations. The underlying CCDS objective is to pursue research that results in products that are economically viable for commercialization. SpARC's mission in meeting

the CCDS objective is to facilitate the commercialization of space and space technologies through the application of automation.

While formulating its mission goals, SpARC organizers looked at the requirements for the successful commercialization of space. They had discussions and meetings with representatives of space-community organizations where the importance of reducing costs and promoting compatibility and interchangeability were stressed. SpARC recognized that one way to meet that need would be through a single document that contained all the guidelines needed by on-orbit spacecraft servicing designers for astronaut extravehicular activity and/or telerobotic servicing.

SpARC envisioned DFOSS as a comprehensive overview document that, as a living document, would provide up-to-date guidelines for designers of serviceable spacecraft. The guidelines would provide a starting point for a designer and would be based on the most current material available.

CONSENSUS AS A GOAL

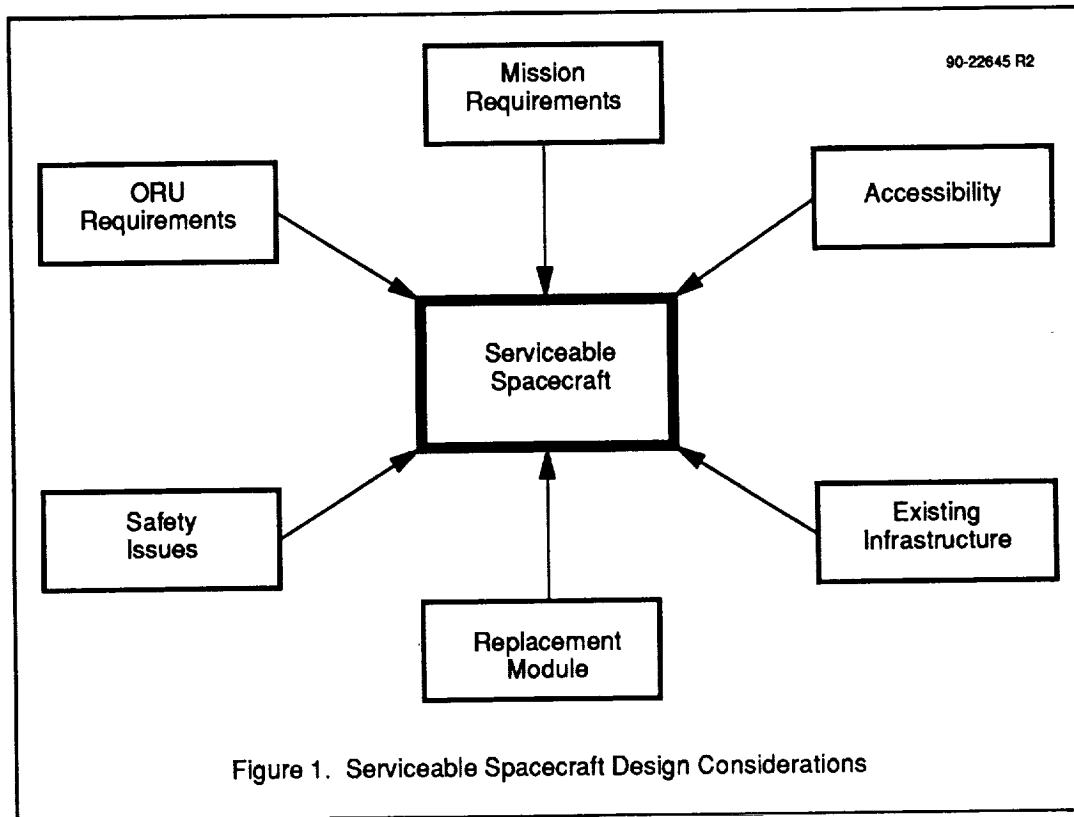
From the beginning of the DFOSS project, SpARC shared its vision of producing a consensus document, promoted the benefits of standardization through consensus, and solicited wide participation. One of SpARC's consortium members, the Industrial Technology Institute, and one of its industrial participants, Fairchild, provided initial material and support at the project's inception in 1988. SpARC provided project management and document production. When SpARC had taken DFOSS as far as it could with the relatively narrow participation taking place within the Center, it more actively sought a wider participation that would bring it closer to the goal of producing an industry-wide consensus document.

In November 1990, the American Institute for Aeronautics and Astronautics (AIAA Serviceable Spacecraft Committee on Standards (SS/COS) adopted DFOSS as a guidelines project. In the context of the AIAA Standards Program, consensus means that every affected person has an opportunity to comment on the draft standard and that those comments are treated in a fair and considerate manner (French 1991). Through the SS/COS DFOSS Working Group, experts from several space-community organizations came together and assumed responsibility for updating and completing the various chapters; SpARC continued its role of project management and document production.

GUIDELINES CONSIDERATIONS

As the SS/COS DFOSS Working Group proceeded, we continued the approach used by SpARC, which was based on the premise that serviceable space-based systems require unique design considerations. These considerations (Figure 1) dictate the options available to a designer

who must develop a viable and cost-effective system. Restrictions and requirements imposed on the design of serviceable space-based systems must be successfully integrated with the requirements and objectives of a particular space mission. If such issues are not considered, the resulting system design will be either too costly or too difficult to maintain.



In addition to the spacecraft design considerations, we targeted two goals for the DFOSS guidelines. We felt it essential that the guidelines:

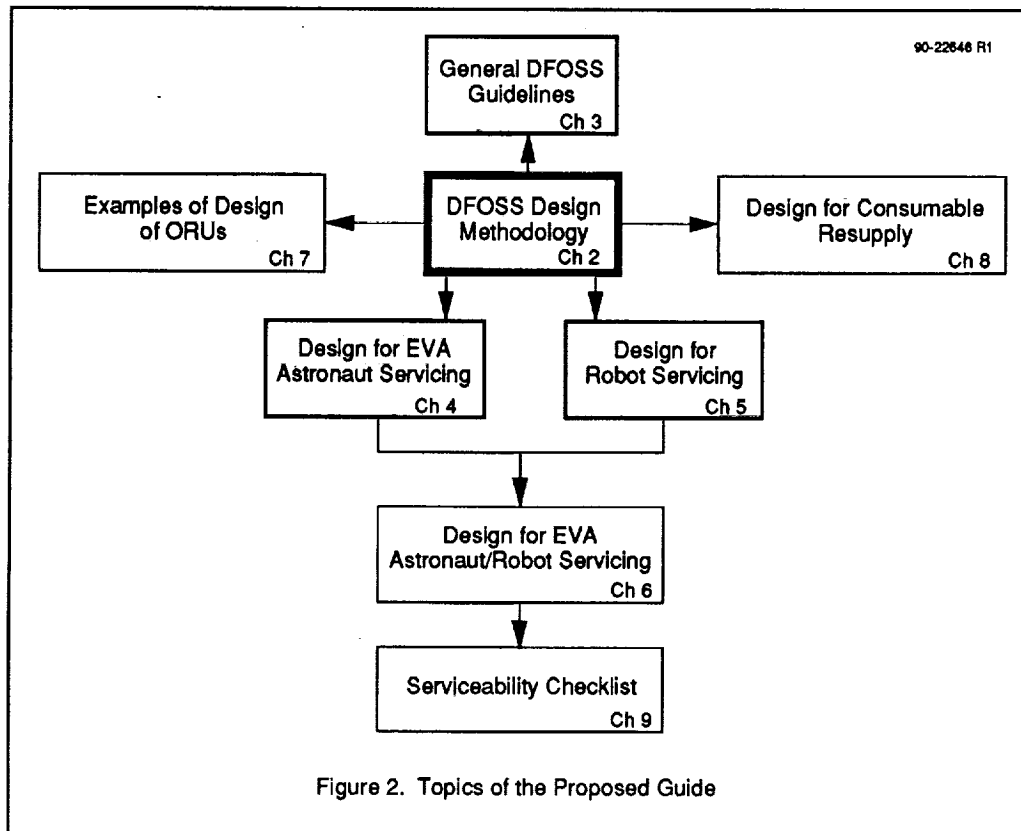
1. Serve as an architecture for: (a) mission-specific guidelines for the design of serviceable spacecraft, (b) specific guidelines for a class of serviceable vehicles, and (c) guidelines for a type of device.

2. Provide an easily referenced format for the information required for a designer to: (a) specify the design requirements and (b) specify the design of serviceable spacecraft.

MANUAL CONTENTS

Through an intensive and dedicated effort by many experts throughout the space community (see Acknowledgments), the Review Copy of the Proposed Guide was completed in the fall of 1991. These guidelines provide a starting point for a designer. Although some of the material has not previously appeared in print, the majority of it is a restatement, reorganization, and compilation of data from valued sources as articulated and selected by the document's many contributors.

The contents of the Proposed Guide flow out of the DFOSS design methodology, with each topic forming a chapter as shown in Figure 2.



The manual is approximately 350 pages long and contains approximately 300 figures. It was written, illustrated, and formatted in an easy-to-read and easy-to-use style, as illustrated by the sample pages in the appendix.

CONCLUSION AND FUTURE PLANS

It is generally understood that guides and standards are only as current, valid, and acceptable as the input that created them. The way to test input is to produce a consensus document that draws on a given discipline as widely as possible. Our first step was to produce the Proposed Guide through the collaboration and input of the Working Group. Our second step was to include critique sections in the Proposed Guide to solicit comments from all users. Third, the availability of the Proposed Guide continues to be announced through AIAA publications, presentations, on-line cataloging, mailings, handouts, and so forth. Based on the feedback from the critiques, the SS/COS DFOSS Working Group will decide how to proceed, using the consensus mechanism, to complete a revised Guide.

ACKNOWLEDGMENTS

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REFERENCE

French, James E., "Draft Standards Introduction for AIAA Publications Catalog," AIAA, Washington, DC, November 1991.

CHAPTER

4

DESIGN FOR EVA ASTRONAUT SERVICING

4.1 INTRODUCTION

This chapter presents guidelines and information for designing equipment and payloads that are intended for servicing by an extravehicular activity (EVA) crew member. EVA can provide an effective means for service, maintenance, repair, or replacement of spacecraft equipment without the need to return the equipment to a pressurized environment, return it to Earth, or abandon it. In a microgravity (zero-g) environment, EVA crew member capabilities, relative to an Earth-based (one-g) environment, are improved for certain functions and degraded for others. The advantages of the space environment allow the crew member unlimited mobility in any direction and relatively effortless translation of equipment and payloads. The main factors that may degrade crew member performance are pressure suit limitations, inadequate crew member restraint, crew scheduling constraints (6 hours), unpredictable crew motion sickness, or improperly designed tools and equipment.

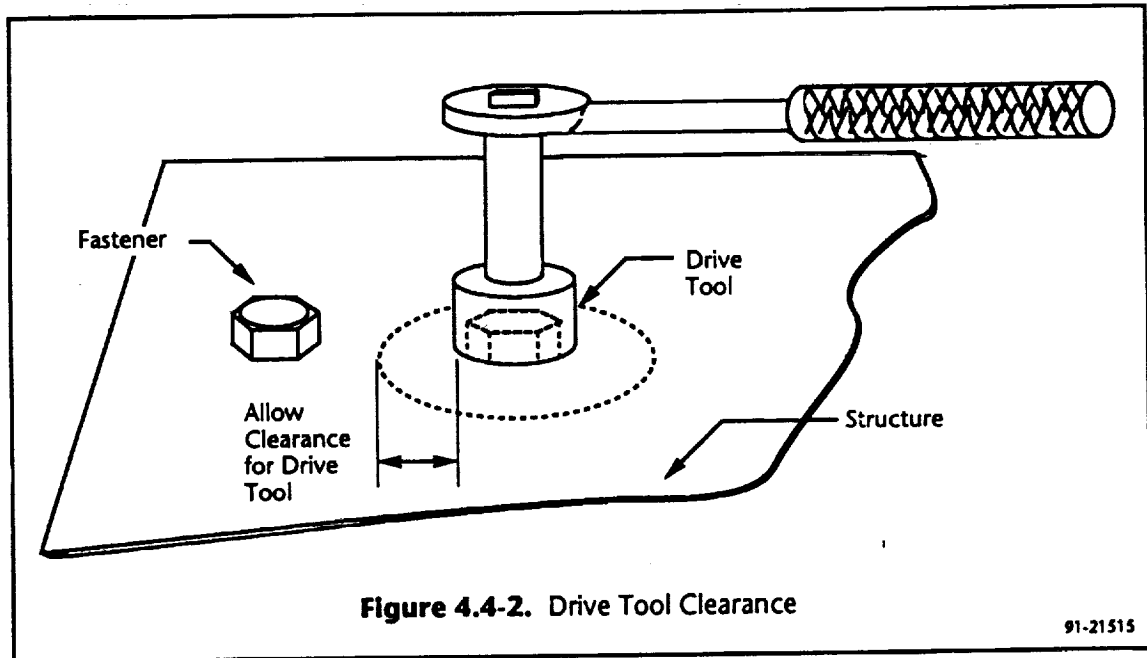
This chapter provides designers with information and data that take into account the capabilities and constraints of an EVA-suited astronaut and provides guidelines for designing equipment and payloads that are compatible with the EVA crew member's physical capabilities and limitations.

The current capabilities and constraints of an EVA-suited crew member and how they influence the design of serviceable equipment and payloads will be addressed in the following sections, which include:

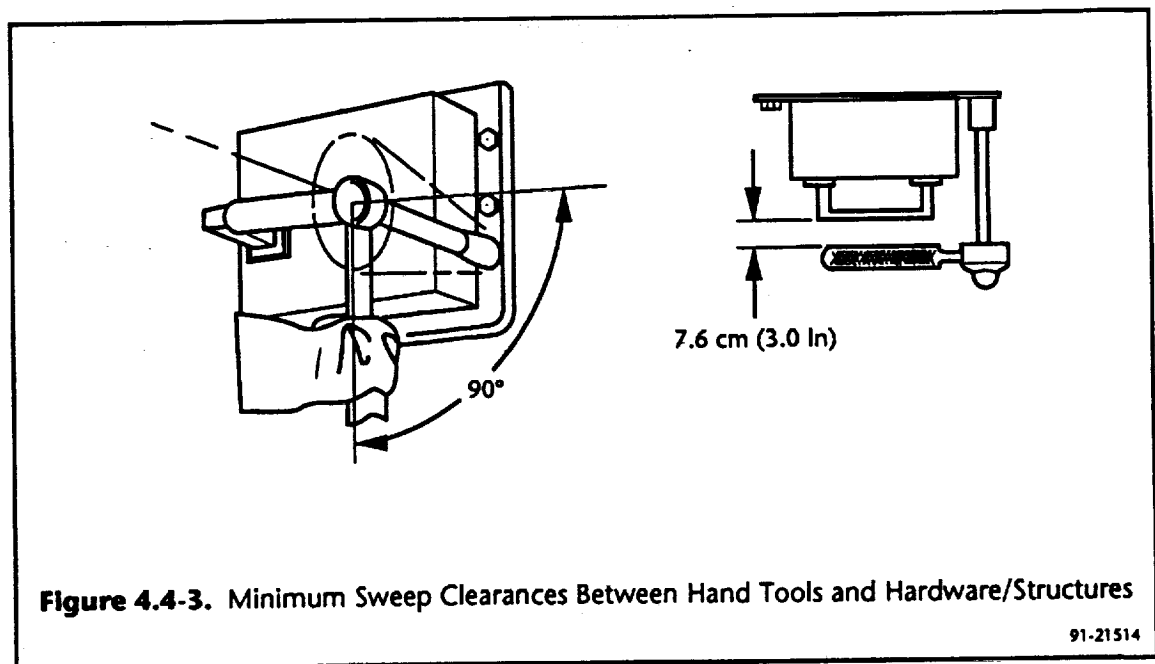
- ALIGNMENT AIDS (4.2)
- ANTHROPOMETRY (4.3)
- CLEARANCES (4.4)
- CONTROLS AND DISPLAYS (4.5)
- ELECTRICAL CONNECTORS AND CABLES (4.6)
- EVA ENHANCEMENT SYSTEMS (4.7)
- EVA RESTRAINT AND LIGHTING EQUIPMENT (4.8)

4.4.3 TOOL CLEARANCE

- **Drive Tool Clearance**—Provide a 2.5 cm (1 in) minimum diameter clearance around fasteners for insertion, actuation, and removal of the drive end of the tool, as shown in Figure 4.4-2.



- **Tool Handle and Surface Clearance**—Provide a minimum of 7.6 cm (3 in) clearance for tool engagement between the tool handle engaged on a fastener or drive stud and the surrounding hardware and structure (e.g., ORU). In addition, the tool handle should be able to maintain this clearance through a full 90-degree operation-envelope as shown in Figure 4.4-3 and should allow right- or left-handed operation.



4.4 CLEARANCES

4.4.1 INTRODUCTION

To facilitate EVA tasks, sufficient clearances between an EVA suit and surrounding structures must be provided. Guidelines for defining these clearances are provided in the following sections:

- EVA Glove Clearance (4.4.2)
- Tool Clearance (4.4.3)
- Translation Route Clearance (4.4.4)

4.4.2 EVA GLOVE CLEARANCE

• *Reaching Into Aperture*—For payload servicing operations that require reaching into an aperture, designers should position equipment as close to the exterior surface as possible and allow sufficient volume for access by the EVA glove and for visibility by the crew.

• *Work Envelope*—The minimum work envelope required for an EVA-gloved hand is shown in Figure 4.4-1. A clearance envelope 20 cm (8 in) in diameter by 36 cm (14 in) [nominal] deep will allow an EVA crew member to manipulate most hand-operated latches, switches, buttons, knobs, and other controls. However, the aperture must be increased for operation of valves, connectors, and latches requiring torquing motions or heavy force application.

